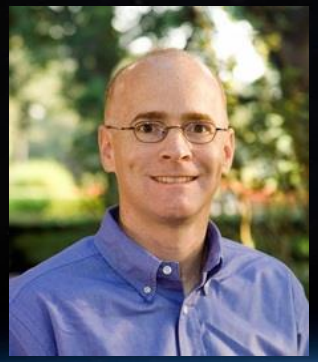
National Aeronautics and Space Administration

RIFD Enabled Autonomous Logistics Management



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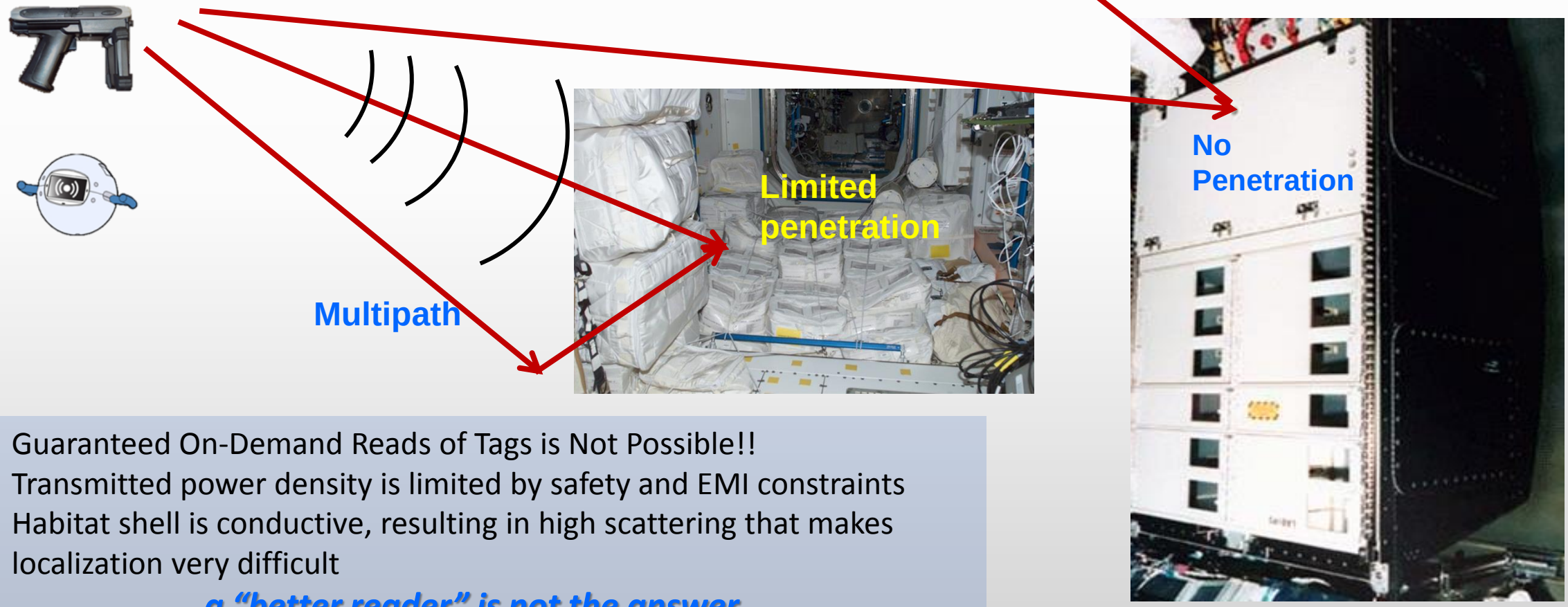
Astronauts on the ISS can spend excessive time looking for supplies and managing inventory. This distracts from their priority tasks.

Passive Tag RFID Challenges in Space Habitat



- Guaranteed On-Demand Reads of Tags is Not Possible!!
- Transmitted power density is limited by safety and EMI constraints
- Habitat shell is conductive, resulting in high scattering that makes localization very difficult

a "better reader" is not the answer

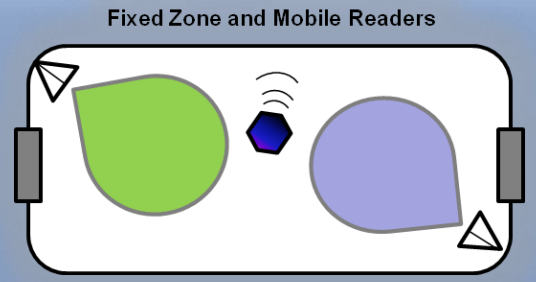
RFID-Based Technologies Enable ALM

DENSE ZONE TECHNOLOGIES

- > 10s or 100s of items in close proximity
- Storage areas capable of identification of densely packed items

SPARSE ZONE TECHNOLOGIES

- All regions exclusive of dense zones
- Covers open regions (elements)
- Longer range identification
- Mobile search elements



SMART / ENABLED APPLICATIONS

- Complex Event Processing (CEP) provides intelligent estimation of location
- Sparse and Dense zone technologies provide data sources

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ALM Definition/Background

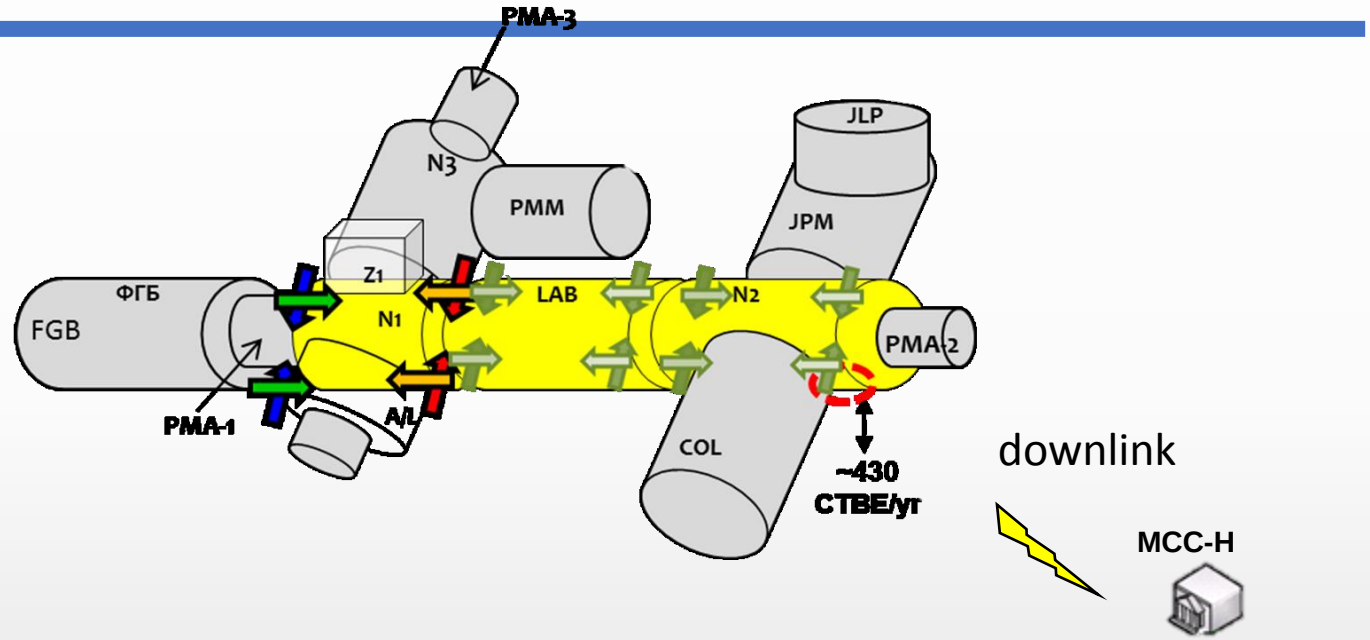
- **Autonomous Logistics Management (ALM) – NASA Technology Area 7.2.1**
  - Provides for the integrated localization, transfer, and status of logistics and mission hardware to facilitate autonomous and automatic decision-making and planning
  - Critical for beyond–LEO human spaceflight missions, in which ground support for finding items is impractical, and re-launch of missing items is not an option
  - Improves packing efficiencies for reduced stowage volume and mass

- NASA's Advanced Exploration Systems (AES) Program, in collaboration with ISS, is embarking on a series of experiments to study effective approaches for ALM in a space habitat environment
  - REALM: RFID-Enabled Autonomous Logistics Management
  - Currently REALM-1, -2, and -3 are in-work at different levels (more detailed discussion follows)

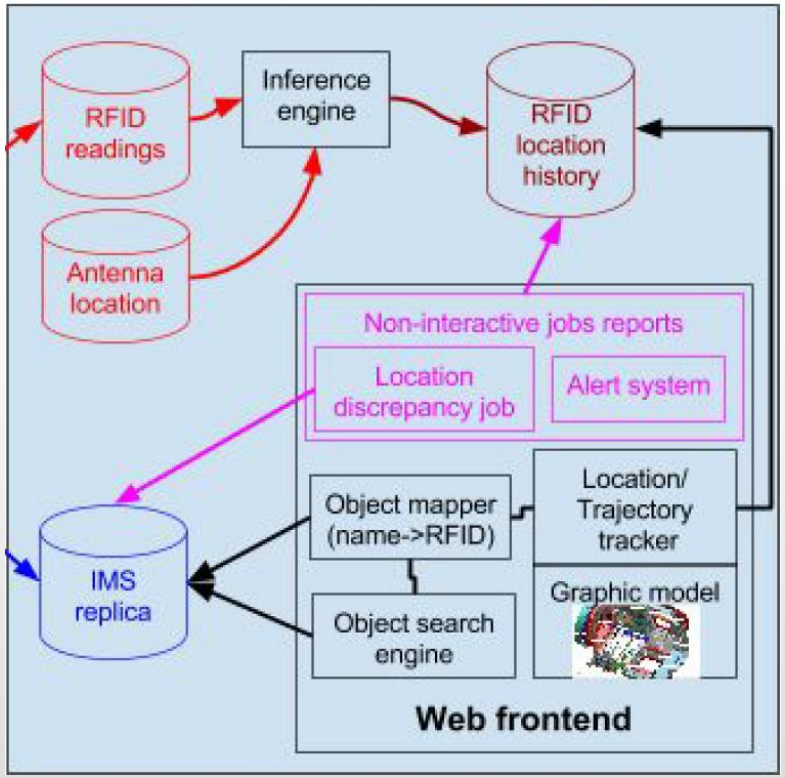
- Overall objective of the REALM experiments is to determine ALM strategies for different deep space missions
  - Optimal RFID solutions might vary depending on specific mission drivers and requirements

REALM-1: Logistics Awareness

- **Primary Objective**: localize tagged cargo with ½-module resolution or better using fixed RFID coverage zones
  - Element modules are ~ 3.5m dia and vary 5.5-8.5m in length
- 6 fixed RFID readers and 24 antennas in 3 modules
- 3 instrumented modules for experimental phase: N1, USL, N2
  - Primary pathway for cargo translation following offload of visiting vehicle
- Data is downlinked to the ground for archival, mining, and Complex Event Processing (CEP)



Ground-Based Complex Event Processing (CEP)



- Collaboration partner: University of Massachusetts, Amherst
  - Applying NSF experience in probabilistic inference over RFID data streams
- Objective: Infer item locations in absence of real time reads, based on data mining of on-orbit tag reads
- Initial spatial resolution goal: approximately ½ element module

REALM-2: Logistics Reconnaissance

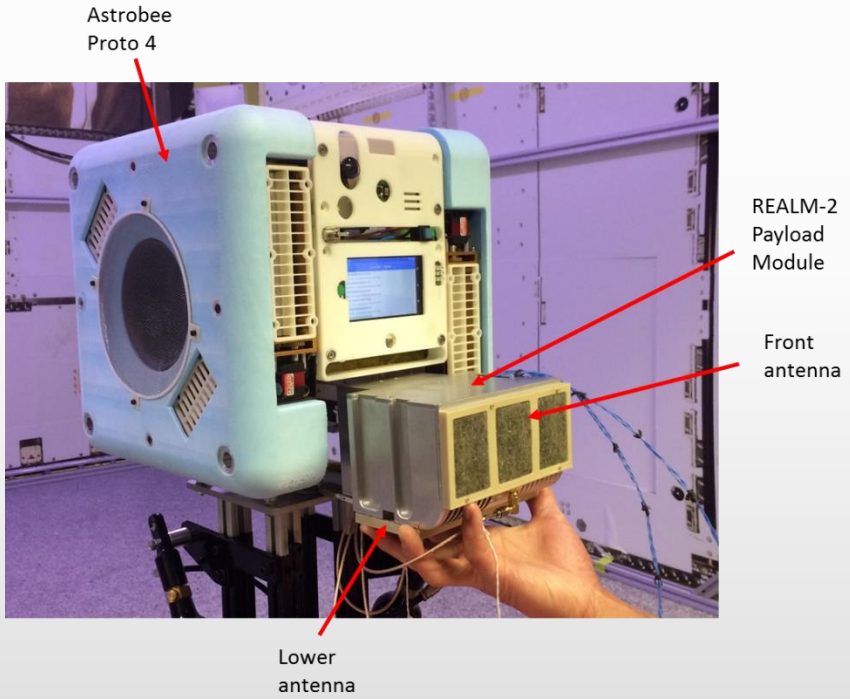
Concept: Robotic free-flyer (Astrobee) equipped with RFID reader and antennas is used to conduct autonomous inventories and searches

- Astrobee, a highly autonomous robotic free-flyer, is under development at NASA Ames Research Center
- REALM-2 is an experimental payload module that attaches to Astrobee

Objective 1: expand RFID coverage area, both in instrumented and non-instrumented modules
  - example: can provide another mobile coverage zone during logistics activities

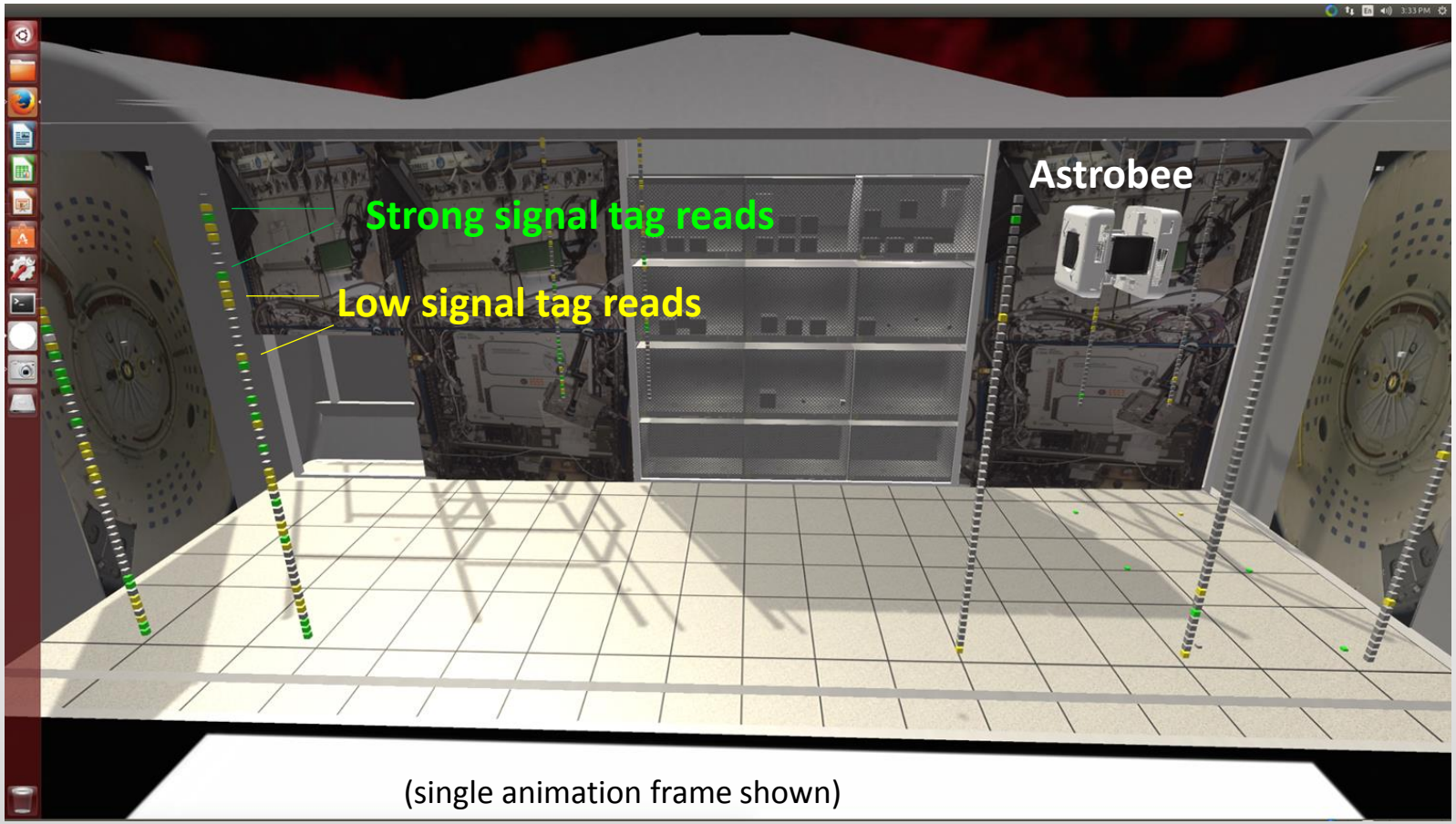
Objective 2: refine item location beyond REALM-1 capability
  - Astrobee location error is estimated at 20 cm

- REALM-1 provides coarse starting point to accelerate searches and minimize robot consumables
- RFID tag data is forwarded to the ground as additional context for CEP inferencing



Astrobee/REALM-2 Early Integration Test – 6/24/16

REALM Simulation



(single animation frame shown)

- REALM Analog Test Bed
- Tags read by REALM-1 fixed readers
  - High level signal strength
  - Mid- to low-level signal strength
- Astrobee sent to read missed tags and/or refine location

REALM-3 Smart Enclosures

- Smart rack drawers identify internal tagged items
- Highly effective in reading large population of densely populated drawers, smart-CTBs, or other suitably designed containers
- Larger “smart” zero-gravity stowage rack (ZSR) enclosures can read hundreds of tagged items in individual compartment cells (next page)
- Provides additional context for ground-based CEP station

“Smart” cargo transfer bag

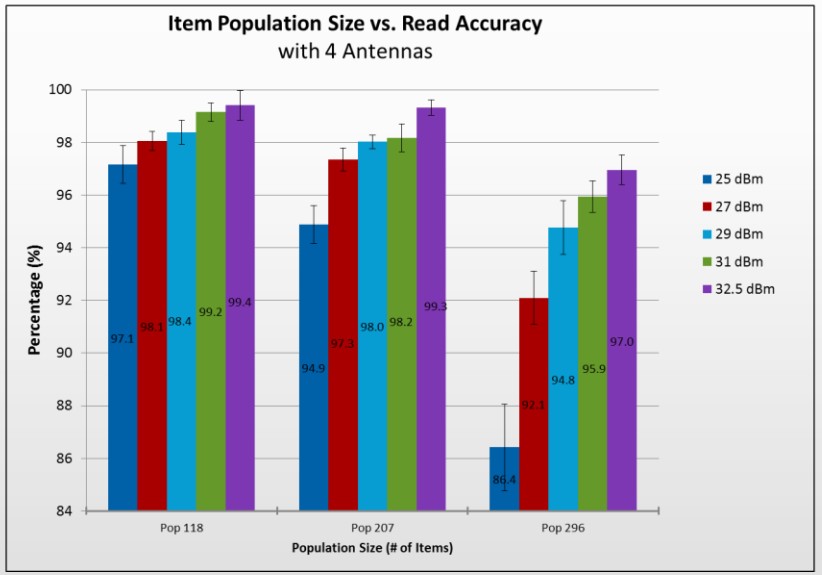
- Conductive fabric shielding in lining provides F isolation for interior volume
- Dimensions: 20” x 19” x 10”

Textile RFID antenna (UHF)

“Smart-ZSR” Tests Conducted for OC

3 ZSR Test Cases

ZSR read accuracy as a function of transmit power for three population sizes (118, 207, 296 items)



- Evaluation of read accuracy from 200mW to 2W
- Conducted to assess battery life when rack power not available
- Even at 200mW, read accuracy > 80%

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Smart Drawer

- Improved signal coverage
- Enhanced localization within drawers
- Thin reader antennas

Medical Operations Work-Station (MOWS) RFID-Enabled Drawers

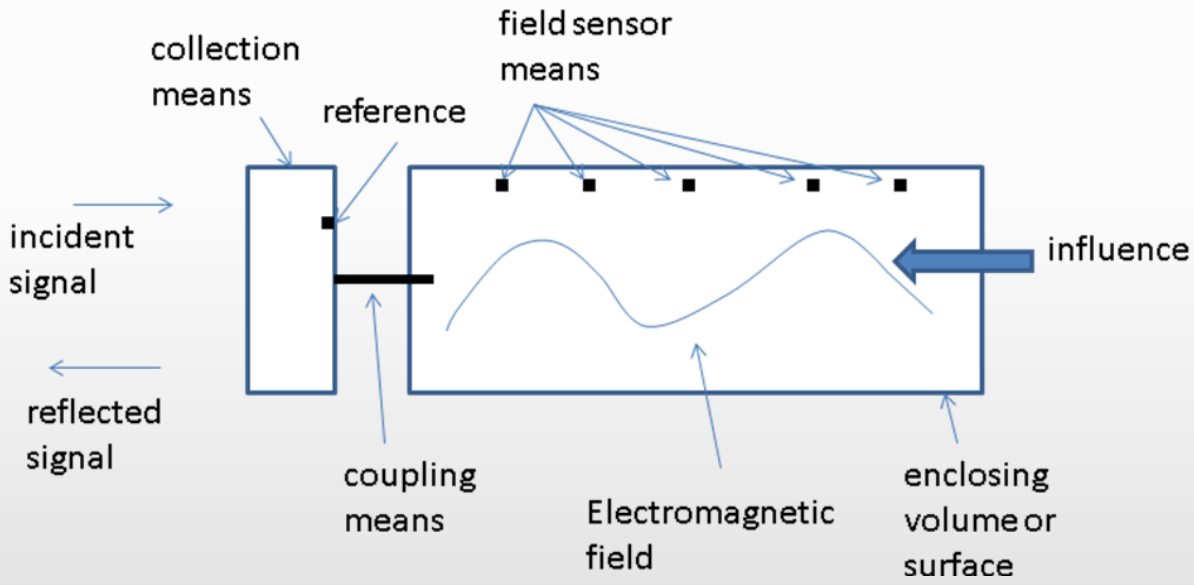
Smart Packaging

Concept: RFID integrated circuits (ICs) embedded in the packaging permit determination of contents without tagging the contained material

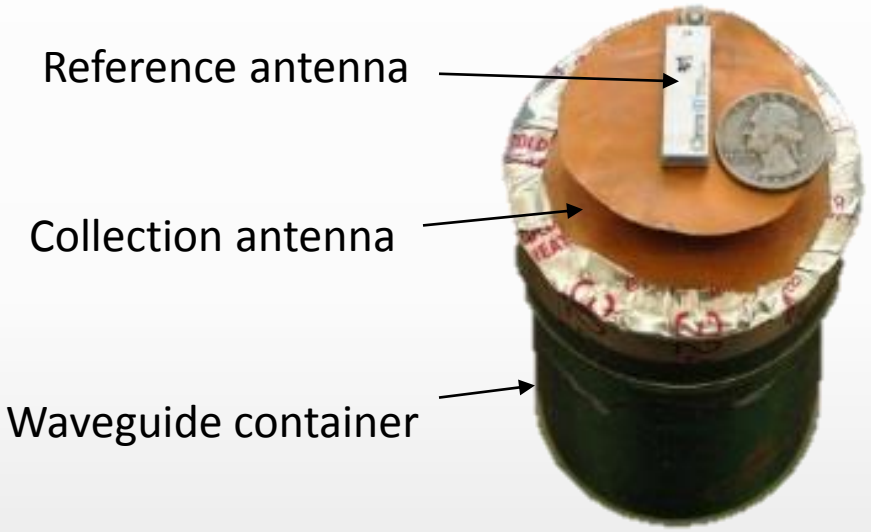
- Applies to tracking items as discrete quantities or to materials as fill volume levels
- Eliminates item-level tagging where manual processing and cost of tags may be prohibitive or impossible
- Packaging containing small items or bulk materials can typically afford more surface area for an RFID antenna than the individual items, enabling greater range and read accuracy

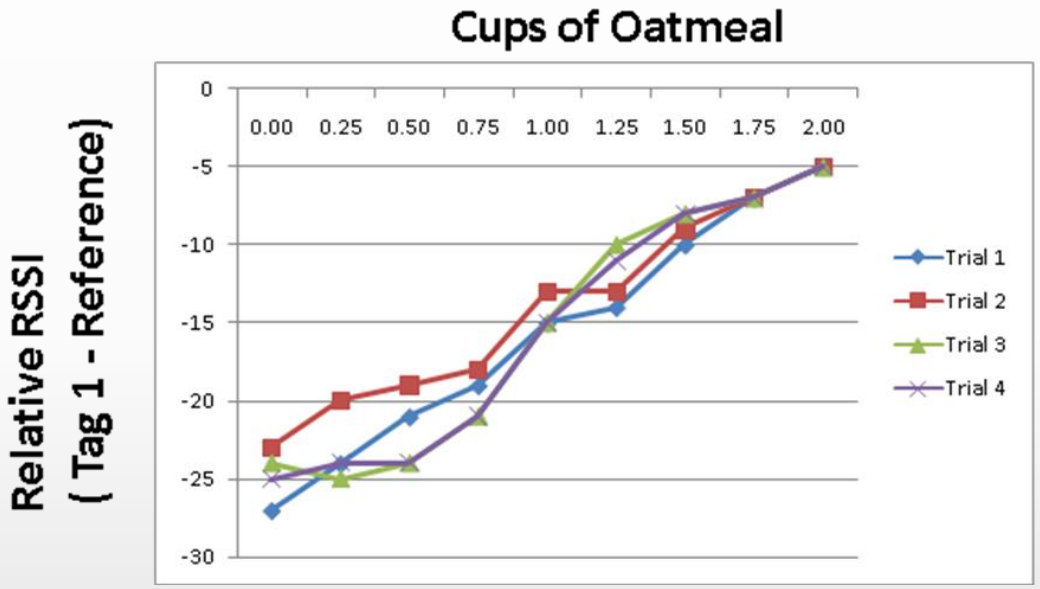
Smart Packaging: Concept 1

- Antenna (“collection means”) receives/returns RFID signal from/to the reader
- RF signal is coupled into a cavity or waveguides (container)
- RFID integrated circuit (IC- field sensor means) are distributed within the cavity or waveguide
- Signal strength and phase associated with each IC is affected by an influence, such as a material stored in the container
- Reader interprets fill level or material based on responses from ICs



Smart Packaging: Example 1





- Reference antenna is used to subtract out variation in the propagation path between the reader and container
- Coaxial waveguide is formed with a coffee can and a metal post that serves as a center conductor and an antenna feed probe
- Signal strength (“RSSI”) changes as a function of oatmeal fill level

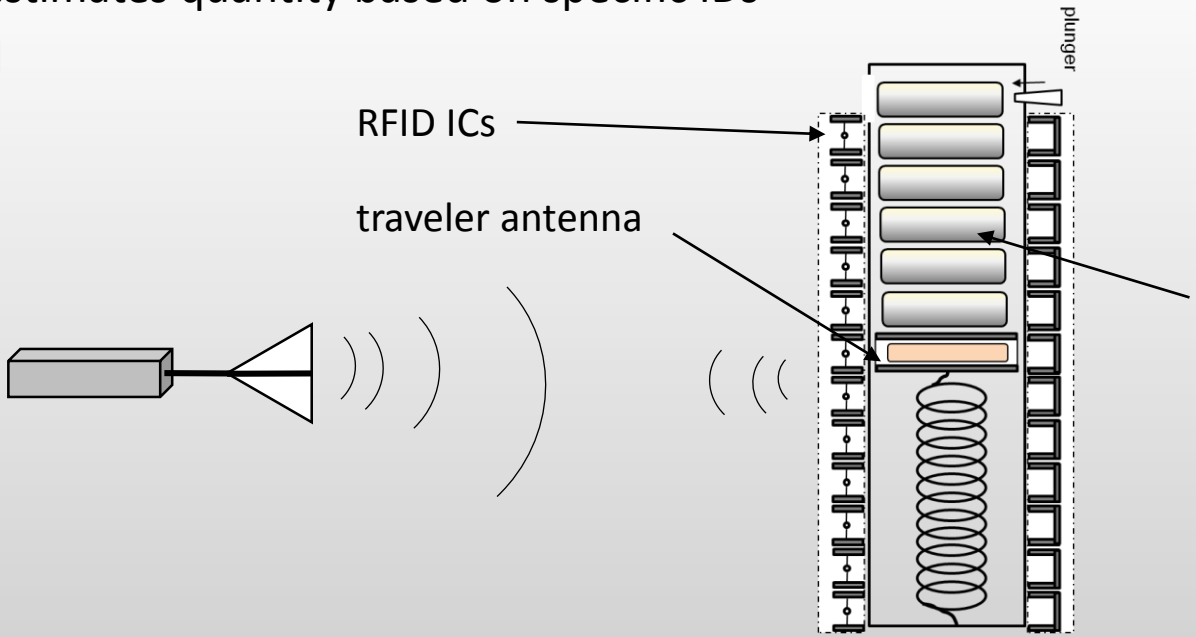
Smart Packaging Concept 2

Concept: packaging tracks discrete quantity of contained items

Can utilize common RFID protocols in wide use

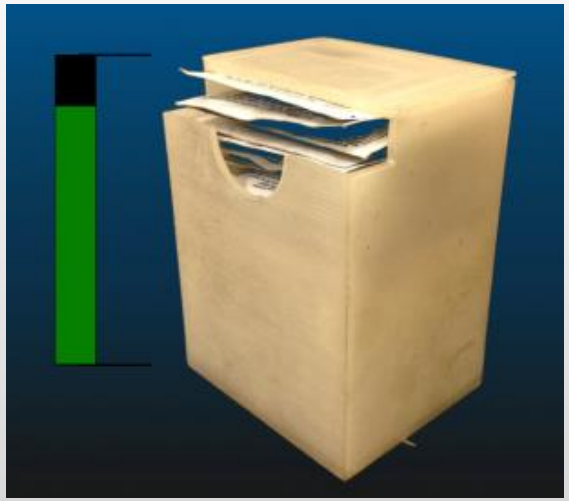
Left: Traveler antenna on spring activates specific RFID integrated circuits when aligned

Reader estimates quantity based on specific IDs returned



Right: Application with ICs embedded in 3D printed housing used to dispense pill packs

Green fill level bar indicates quantity remaining in web app



RFID-Tracking Pill Dispenser

National Aeronautics and Space Administration

Technology Opportunity: RFID based Smart Enclosure

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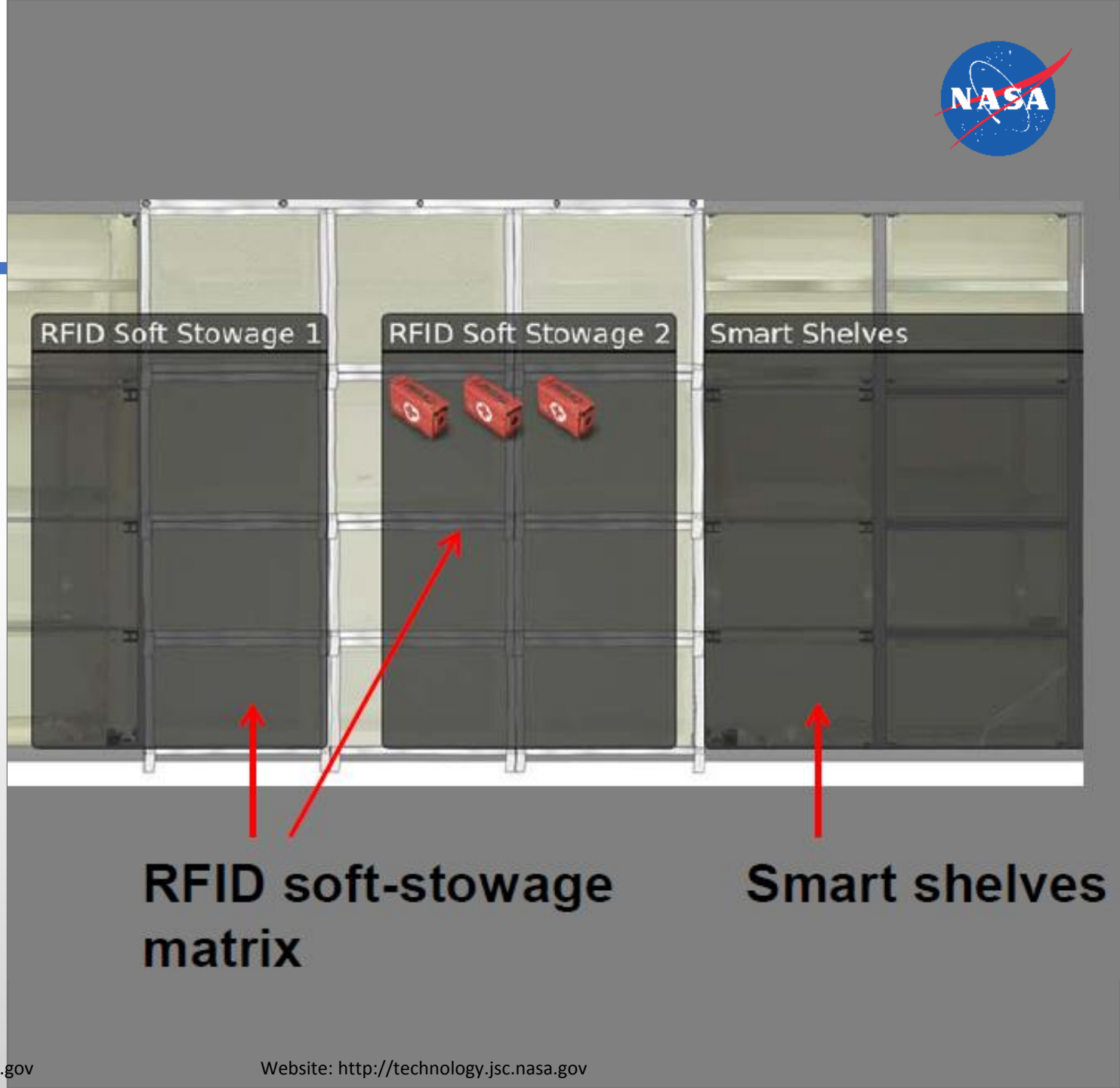
TECHNOLOGY TRANSFER PROGRAM
BRINGING NASA TECHNOLOGY DOWN TO EARTH

Smart Enclosure

- 1 US Patent (US9208362)
- 3 patents pending
- Track and locate small or large items
- High level of accuracy in dense environments
- Reduce size and tag cost
- Versatile enclosure possibilities



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Potential Applications

Inventory and logistics

Cruise ships & hotels

Crime evidence

Surgical room

Image: http://www.modernofficesystems.com/wp-content/uploads/StockBox-FrameWRX-Medical-Supply-Storage-Wyoming-Medical-Center_mr.jpg

- Patient direct care begins when caregivers have required supplies and equipment
- Smart logistics enable efficient cost and operations

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Hypothetical Application

Hospitals and Nursing Care Systems

-- autonomously advise caregivers of the location, inventory, and history of supplies or equipment, enabling improved direct care of patients while reducing inventory management costs

Potential Application: Hospital Asset Managment

Medical Storage

Patient Room

Inventory Management System 9:05AM LOG

Nurse: A. Lin

IV Code: AB3902 Patient: J. Smith

Inventory Low (2 Qnt) Alarm 5

Image: https://cdn3.nursinglicensemap.com/content/9d3968d2dc1b4bdeb09b74e20999ade4/Registered_nurse.jpg

Interested?

Opportunities:

- License
- Evaluate
- Co-develop

Including new start-up:

Startup NASA

Website: http://technology.nasa.gov/startup

National Aeronautics and Space Administration

RFID Autonomous Logistics Management Q & A

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